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Formation of Plant Communities of the Newly Created Wetland in Modern Yellow River Delta

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Abstract

To explore the cause of plant vegetation distributed on the newly created wetland in estuary of modern Yellow River Delta, we took field-based observation of the wetland plant diversity of the Yellow River Delta, Shandong, China. Based on the results of field investigation, we studied the effects of salinity on germination characteristics of four dominant species in wetland of Yellow River Delta, i.e. Suaeda salsa, Apocynum venetum, Phragmites australis and Typha orientalis.The germination conditions of the four dominant emerging plants at 0, 50, 100, 150, 200, 250 and 300 mM NaCl were studied, the results indicated that all species had a trend of decreased germination percentage and rate of germination with the increase of salinity levels, but the inhibitory effect of salinity on the germination percentage of each was different. S. salsa and A. venetum had higher tolerance of salinity than P. australis and T. orientalis. Germination percentage and germination rate of seeds of the four species were significantly affected by salinity.In conclusion, the results of seeds germination of the four dominant species in the newly created wetland were accorded with the results of field investigation of plant community distribution along the gradients of environmental salinity, and salinity is one of the most pivotal factors limited the distribution of the plant vegetation in the newly created wetland of Yellow River Delta.

Key Words: Yellow River Delta; wetland; germination; salinity; plant communities.

1. Introduction

The modern Yellow River Delta is located at the mouth of the Yellow River flowing to the sea, north of Shandong Province, China [1]. Massive sediment transport brings fertile soil from the Loess Plateau of central China to the river mouth leading to expansion of Yellow River Delta by 20-25 km^2 per year [2, 3]. It is the youngest land in the east of China, and there exists the broadest, youngest and the most integrated wetland ecosystem [4]. The wetland in Yellow River Delta is a typical ecosystem of littoral wetland in estuary, in which there are rich wetland vegetation and hydrobios. It is an important transfer station, wintering habit and

breeding farm for birds in northeast Asian in land and the Pacific area [5-7]. The newly created wetland situated in the zone of sea-land interacts and the phenomenon of storm tide and soil salinization is widespread [5, 7].

The wetland ecosystem contains the highest productivity of all the ecosystems [7]. The wetland ecosystems of Yellow River

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Delta are changed with the waving of the Yellow River mouth and the land development in the Delta area, and salinity is a pivotal factor influencing coastal and estuarine ecosystems [8]. However, it is noteworthy that the retrogressive succession of plant communities in the Yellow River Delta wetland is obvious gradually [5, 7].

There were many researches about the plant community of modern Yellow River Delta, e.g., the characteristics and the main types of vegetation [6, 9], the characteristics and succession of vegetation [1, 7], soil and vegetation characteristics of wetland community [5], interrelation between vegetation and soil salinity [10], spatial distribution and ecological adaptability of wetland vegetation along a water depth gradient [11-13], but seldom focus on the formation mechanism of the plant community diversity. So we studied the effects of salinity on seed germination of four dominant herb species present at the newly created wetlands in Yellow River Delta.

A better understanding of community distribution and its pattern to-be is needed for wise management and protection of the newly wetland in Yellow River Delta.

2. Materials and methods

2.1. Study area

The newly created wetland of Yellow River Delta consists of mouth of Yellow River current course to Bohai Sea and area close to the mouth. It is located in 37°35'- 37°54'N and 118°43'- 119°20'E (Fig. 1).

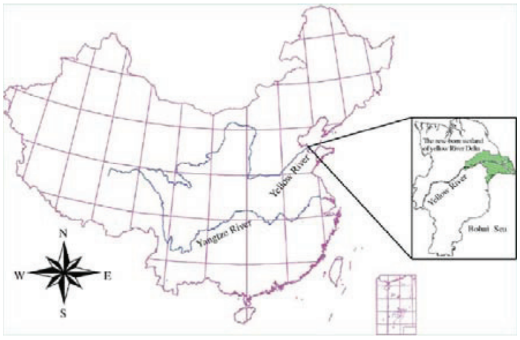

Fig. 1. Location of the newly created wetland of Yellow River Delta [6]

2.2. Field- based observation of the wetland plant diversity of the Yellow River Delta

For purposes of this study, plant vegetations of 10 typical plots (10 quadrats each plot) were investigated in the newly created wetland of Yellow River Delta (Fig. 1) between May and June 2008. Quadrat sizes were 2 m× 2 m for shrub-dominated and 1 m× 1 m for herb-dominated communities, respectively. Dominant species and cover (%) were recorded for each quadrat, and EC (electrical conductivity) was measured by FS 2265 Field Scout® Soil and Water EC Meter (Spectrum Technologies, USA).

2.3. Effects of salinity on seed germination of four dominant species

Seeds of *S. salsa*, *A. venetum*, *P. australis* and *T. orientalis* were collected during May 2008 from the wetland of Yellow River Delta in Dongying, China. Seeds were surface sterilized using 0.1% $HgCl_2$ for 5 min followed by a thorough rinsing in distilled water 4-5 times. Germination was conducted in 9 cm Petri dishes containing double-deck of filter paper, with 5 ml of test solution. Each dish was placed in a 10-cm-diameter plastic Petri dish as an added precaution against loss of water by evaporation.

Germination experiments were conducted in incubators with a cycle 14 h (25 °C) day and 12 h (20 °C) night. Seeds were germinated in 0, 50, 100, 150, 200, 250 and 300 mM NaCl solutions, with electrical conductivity values of 0.005, 5.1, 9.1, 12.5, 15.4, 19.9, 23.8 ds·m^{-1}, respectively. Five replicates of 20 seeds each were used for each treatment. Seeds were considered germinated when the radicle emerged 1 mm from the seed [14-16]. The number of germinated seeds was counted daily for 7 d following seed sowing. The rate of germination was estimated by using a modified Timson index of germination velocity (GI), $\Sigma G/t$, where G is percentage of seed germination every day, and t is total germination period [17]. The maximum value possible was 700/7= 100. The higher the value, the more rapid is the germination [16, 18]. The length of seedlings (LS) was measured after 7 d following seed sowing. GI and VI are two important indexes to indicate the quality of seeds [19, 20]. The index of seed vigor (VI), GI* LS [21, 22], where GI is index of germination velocity and LS is the length of seedlings, was also used.

2.4. Statistic analysis

A one-way analysis of variance (ANOVA) was carried out to test effects of salinity on the final percentage of germination. Tukey test (Honestly significant differences, HSD) was used to estimate least significant range between means. All statistical methods were performed using SPSS version 16.0 and Origin version 7.0.

3. Results

3.1. Field investigations of the newly created wetland in Yellow River Delta

The results of the field investigations of the newly created wetland in Yellow River Delta showed that salinity had a decreasing trend from the coast to inland, and obvious succession was existed between plant communities (Table 1).

Table 1. The species composition and characteristics of vegetations of the newly created wetland communities in different sampling plots

No. of plots	Location of plots	EC ($ds \cdot m^{-1}$)	Main dominant species
1	N: 37°44'2.06” E: 119°10'0.35”	50	*Tamarix chinensis*, *Suaeda salsa*, *Apocynum venetum*
2	N: 37°44'33” E: 119°11'26.1”	24.10	*Suaeda salsa*
3	N: 37°44'32.4” E: 119°11'23.7”	21.00	*Suaeda salsa*, *Apocynum venetum*, *Phragmites australis*
4	N: 37°43'20.5” E:119°12'56.7”	20.95	*Phragmites australis*, *Limonium sinense*
5	N: 37°43'58.5” E: 119°12'10.0”	20.50	*Suaeda salsa*, *Phragmites australis*, *Limonium sinense*
6	N: 37°43'33.1” E: 119°12'41.1”	19.60	*Suaeda salsa*
7	N: 37°43'58.1” E: 119°12'09.4”	18.50	*Suaeda salsa*, *Phragmites australis*
8	N: 37°43'09.6” E: 119°13'12.7”	10.48	*Suaeda salsa*, *Phragmites australis*
9	N: 37°44'47.9” E: 119°08'59.0”	1.52	*Typha orientalis*, *Phragmites australis*
10	N: 37°45'33.6” E: 119°09'29.1”	1.43	*Phragmites australis*, *Apocynum venetum*, *Suaeda glauca*, *Typha orientalis*

Note: EC, electrical conductivity.

3.2. Effect of salinity on seed germination percentage of the four emerging plants

The results indicated that non-salt treated seeds of *A. venetum*, *P. australis* and *T. orientalis* had the highest germination percentage, while the highest germination percentages of *S. salsa* appeared in 50 mM treatment (Fig. 2 and Fig. 3). But *S. salsa* also had a decreasing trend of germination percentage with the increase of salinity level.

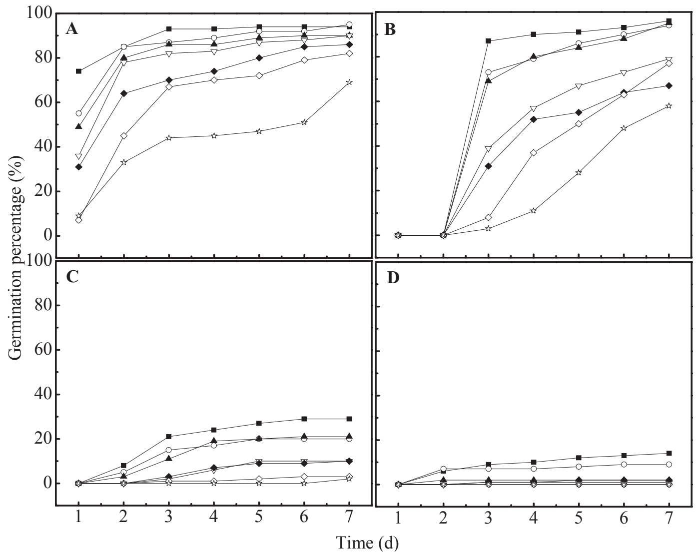

Fig. 2. Germination percentages of *Suaeda salsa* (A), *Apocynum venetum* (B), *Phragmites australis* (C) and *Typha orientalis* (D) after different salinity treatments: seeds were germinated in 0(■), 50(○), 100 (▲), 150 (▽), 200 (◆), 250 (◇), 300 (☆) mM NaCl.

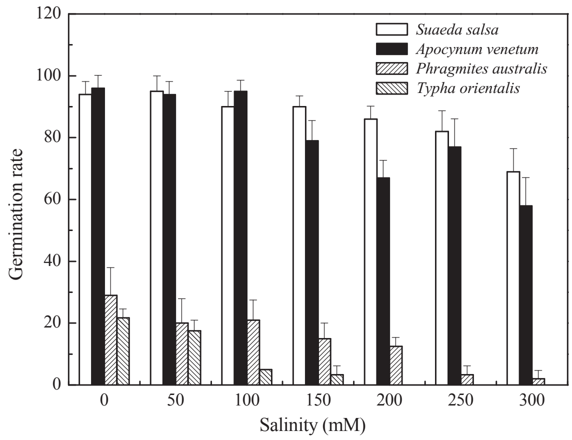

Fig. 3. Effects of salinity of incubation on of four species seeds in 0, 50, 100, 150, 200, 250 and 300 mM NaCl at thermoperiod of 20/ 25 °C

S. salsa and *A. venetum* had high germination percentage (> 90%) when the salinity was less than 100 mM NaCl, and still had higher germination percentage (> 60%) even on the highest salinity condition (300 mM NaCl). *T. orientalis* could only geminated on the lower salinity conditions, no seeds of *T. orientalis* were germinated when the concentration of NaCl over 200 mM.

One-way ANOVA indicated that germination percentage of seeds of the four species was significantly affected by salinity (Table 2). The result indicated that salinity was one of the pivotal factors on seed germination of plants.

Table 2. Results of a One-way ANOVA showing effects of salinity ongermination percentage in the four species

Species	*df*	Mean-square	*F*-ratio	*P*
Suaeda salsa	6	28.21	14.16	<0.001
Apocynum venetum	6	41.07	27.08	<0.001
Phragmites australis	6	37.46	11.37	<0.001
Typha orientalis	6	19.54	9.92	<0.001

3.3. Effect of salinity on GI and VI of the four species

The index of rate of germination of the four species calculated using a modified Timson index showed that the rate decreased with the increase in salinity concentration (Table 3). The results indicated that non-salt treated seeds of *A. venetum*, *P. australis* and *T. orientalis* had the highest GI. *S. salsa* had the highest germination rate both in non-salt and high salt treatment and *T. orientalis* had the lowest germination rate both in non-salt and high salt treatment in the four species.

Table 3. Index of rate of germination (GI) of the four species using modified Timson index [17]

NaCl	Species			
(mM)	*Suaeda salsa*	*Apocynum venetum*	*Phragmites australis*	*Typha orientalis*
0	89.57±4.45	65.29±1.93	19.71±5.55	9.14±7.10
50	85.00±4.60	60.29±3.80	13.86±4.62	6.71±5.71
100	81.43±4.60	59.43±1.71	13.57±3.68	1.711±2.35
150	77.71±2.69	45.00±5.13	5.43±3.80	0.71±1.60
200	70.00±3.94	38.43±4.67	5.43±4.09	1.14±1.64
250	60.28±4.24	33.57±3.07	1.43±2.20	0.00±0.00
300	42.57±3.66	21.14±4.75	0.29±0.39	0.00±0.00

(Mean ± S.E.: n=5)

S. salsa had high germination rate (> 80%) when the salinity concentration was less than 100 mM, and the germination rate decreased to 42.57 % when the salinity concentration was 300 mM. *T. orientalis* was absolutely inhibited when the concentration of NaCl over 200 mM, and the germination was completely inhibited.

Salinity significantly inhibited the germination rate of the four species (Table 4). Effect of salinity on VI of the four species showed the same trend of germination rate. *S. salsa* had the highest VI in 100 mM NaCl treatment, and was different from *A. venetum*, *P. australis* and *T. orientalis* (Table 5).

Table 4. Results of a One-way ANOVA showing effects of salinity on rate of germination in the four species

Species	*df*	Mean-square	*F*-ratio	*P*
Suaeda salsa	6	16.625	80.48	<0.001
Apocynum venetum	6	14.45	91.49	<0.001
Phragmites australis	6	14.54	18.14	<0.001
Typha orientalis	6	13.38	4.95	<0.01

Table 5. Index of seed vigor (VI) of the four species.

NaCl	Species			
(mM)	*Suaeda salsa*	*Apocynum venetum*	*Phragmites australis*	*Typha orientalis*
0	150.48±7.47	86.18±2.55	35.10±9.87	4.88±3.788
50	139.4±7.55	60.89±3.84	24.53±8.17	2.52±2.14
100	244.29±13.80	41.01±1.18	22.39±6.07	0.51±0.70
150	240.14±8.32	16.65±1.90	7.71±5.40	0.18±0.40
200	177.10±9.98	12.68±1.54	6.62±4.99	0.00±0.00
250	147.70±10.40	11.75±1.08	0.71±1.10	0.00±0.00
300	103.45±8.90	6.34±1.43	0.09±0.12	0.00±0.00

(Mean ± S.E.: n=5)

4. Discussion

The newly created wetland in Yellow River Delta, one of the most rapidly growing wetland ecosystems in estuary of the world, is one of the three main estuarine deltas in China and is also the fastest one to be formed of the estuarine deltas in the world [7, 11]. Plant vegetation in the newly created wetland is on the initial stage of coming into existence and development. With land extending into Yellow Sea, plant vegetation spreading toward sea shore, and frequent succession among vegetation communities existed. Because of these characteristics, the newly created wetland in Yellow River Delta is very fragile [6]. However, it is noteworthy that the retrogressive succession of vegetation communities in the Yellow River Delta wetland is obvious gradually [5, 7]. The stability of vegetation communities is the precondition of the stability of ecosystem. One of the ecological tenets justifying conservation of biodiversity is that diversity begets stability. The preservation of biodiversity is essential for the functioning and sustainability of ecosystems and the maintenance of stable productivity in ecosystems [23, 24]., while loss of biodiversity will alter or impair the biogeochemical functioning of ecosystems [25, 26]..

The seed germination is one of the key events in the life cycle of plants, because it determines plant performance and success [27], and the seedling stage that is the most vulnerable stage in plant development [18], influenced by a complex combination of different abiotic and biotic factors that determine the mode by which natural selection acts on emergence time [27]. The timing of seedling emergence is critical to plant performance in habitats subject to frequent disturbances [28].

The chenopodiaceous *S. salsa* is a typical halophyte with leaf-succulent euhalophytic which have the capable of surviving under high salinity [29-31], and in the very estuary of the Yellow River Delta, *S. salsa* was the only dominant specie and had a great coverage in the district [7]. *S. salsa* is the early-successional plant specie in Yellow River Delta [10]. Early-successional plant species typically have a series of correlated traits, including high fecundity, long dispersal, rapidly growth when resources are abundant, and slow growth and low survivorship when resources are scarce [32]. It is very well established from the survey of previous literature that most halophytes can not only germinate, but germinate better, under non-saline conditions. Seeds of halophytes vary in their ability to tolerate salinity at the germination stage of development [18]. The results of seeds germination of *A. venetum* were accorded with the previous studies. While the highest GI and VI of *S. salsa* appeared in 50 and 100 mM salinity treatment, respectively, and GI was decreased with the increase of salinity level (>200 mM NaCl). The annual plant *S. salsa* had a short life story of four months and with a higher tolerance of salinity yet, while the perennial plant *A. venetum* had a lower tolerance of salinity in stage of germination. The results provide evidence for the conclusions that *S. salsa* as early-successional plant specie survived in the condition with higher salinity [10]. After the community of *S. salsa* formed, the soil salinity reduced via absorbing salt and the organic material accumulated in the soil because of the metabolism of plant. Then, the soil with lower salinity became suitable for the seeds germination of other species, e.g. *Imperata cylindrica*, *A. venetum* and *Limonium bicolor* [10].

The maximum germination percentage of *P. australis* and *T. orientalis*, two perennial glycophytes, were obtained in the non-salt control. Germination percentage of *P. australis* and *T. orientalis* were significantly decreased with the increase in salinity, and were substantially inhibited at 300 and 200 mM NaCl treatment, respectively. With the salinity of soil decreased further, *P. australis* and *T. orientalis* appeared in the newly created wetland. Then, the successions of vegetation communities in the Yellow River Delta wetland were formed.

In conclusion, the results of seed germination of the four dominant species in the newly created wetland were accorded with the results of field investigation of plant vegetation distribution along the gradients of environmental salinity. And salinity was one of the most pivotal factors limited the distribution of the plant vegetation in the newly created wetland of Yellow River Delta.

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